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ENGOBES FOR CERAMIC BRICK

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Engobing is used to expand the color range for the facial surface of brick. A light-colored engobe composition has been developed, using red-fire clays followed by the addition of various pigments, to regulate color. The rheological properties of the engobe slips are studied and the quantity of electrolytes is optimized.

Additional methods of finishing a brick surface are needed in order to expand the color range of the facial surface of bricks. One such method is engobing. Together with increasing the architectural – artistic advantages, engobing makes it possible to eliminate surface defects of brick, such as "salting out" and color nonuniformity.

On account of the capability of engobes to form a fired surface film that is sufficiently dense so that water from air and dissolved salts cannot pass through the film, such brick does not show seasonal discoloration, and the ability of coloring engobe materials with stable inorganic natural or synthesized pigments makes it possible to expand the color range of articles.

The color of a composition can be regulated in a desired manner only if the matrix has a light color. Consequently, the first problem of the present investigation was to develop an engobe composition with a light color based on the red-firing low-melting clay from the Novokubanskoe deposit "Khutorok," the same clay that was used to make the brick itself. Similar materials must be used so that the CLTE of the ceramic base matches that of the coating.

It is well known that the decrease of the intensity of the red color of red-firing clays can be regulated by introducing carbonate materials, such as chalk, into the mixes [1]. But, in addition to bleaching, at brick firing temperatures near 1000°C carbonates decrease substantially the capability of the mixes to sinter, since at these temperatures only intense decarbonization of chalk occurs and the alkali-earth components do not act as fluxes. Consequently, cullet was added to the engobe mixes in order to intensify sintering.

Mathematical methods of planning, specifically, accumulation analysis, were used to work out the optimal composition of a light-colored engobe and subsequent experiments [2]. The contents of clay, chalk, and cullet ($X1$, $X2$, $X3$) were chosen as the factors controlling the compositions of the engobes. Three-dimensional plots with the ability to project a two-dimensional triangle onto a plane were used as the coordinate system. Scheffe's simplex-centroid plan was chosen to analyze the results.

Since the engobe must form on the brick surface a dense, fired, 0.1 – 0.3 mm thick layer with low porosity and minimal water absorption, the water absorption, the Mohs hardness of the engobe, and the intensity of red color were chosen as the response functions. The sum of the components for each mixture was equal to 1, so that their values were interpreted as proportions, since the coordinate of any vertex of a component equals 1 (100%) and 0 for all other components. On this basis it is possible to calculate the position of each point inside the triangle and plot a fourth dimension — the values of the dependent variable (response function).

The statistical analysis of the experimental data on the water absorption and hardness of the engobe and the color intensity was performed following the procedure described in [3]. The experimental data and computed values are presented in diagrams (see Fig. 1*a* – *c*).

The engobe compositions with the highest degree of sintering and strength lie near the point $X3$ where the amount of cullet is substantial. At this point the water absorption is 8.08% (the water absorption of the brick without engobe is 14 – 15%), and the Mohs hardness of the engobe layer is 4. The engobe compositions with lightest color lie near the point $X2$, where the amount of chalk is substantial. The decrease of the red color intensity is greatest here and equals 85% on the color scale. However, these compositions exhibit the lowest hardness and high water absorption. Consequently, the optimal composition was chosen along the line $X2$ – $X3$ in the region where the water absorption is 9% and the red color intensity decreases by more than 80%.

The increase of the density and strength of the engobe depends on the crystalline phases which are formed during firing. X-ray phase analysis showed that the main crystalline phases in fired engobe are anortite, calcium silicates, and quartz.

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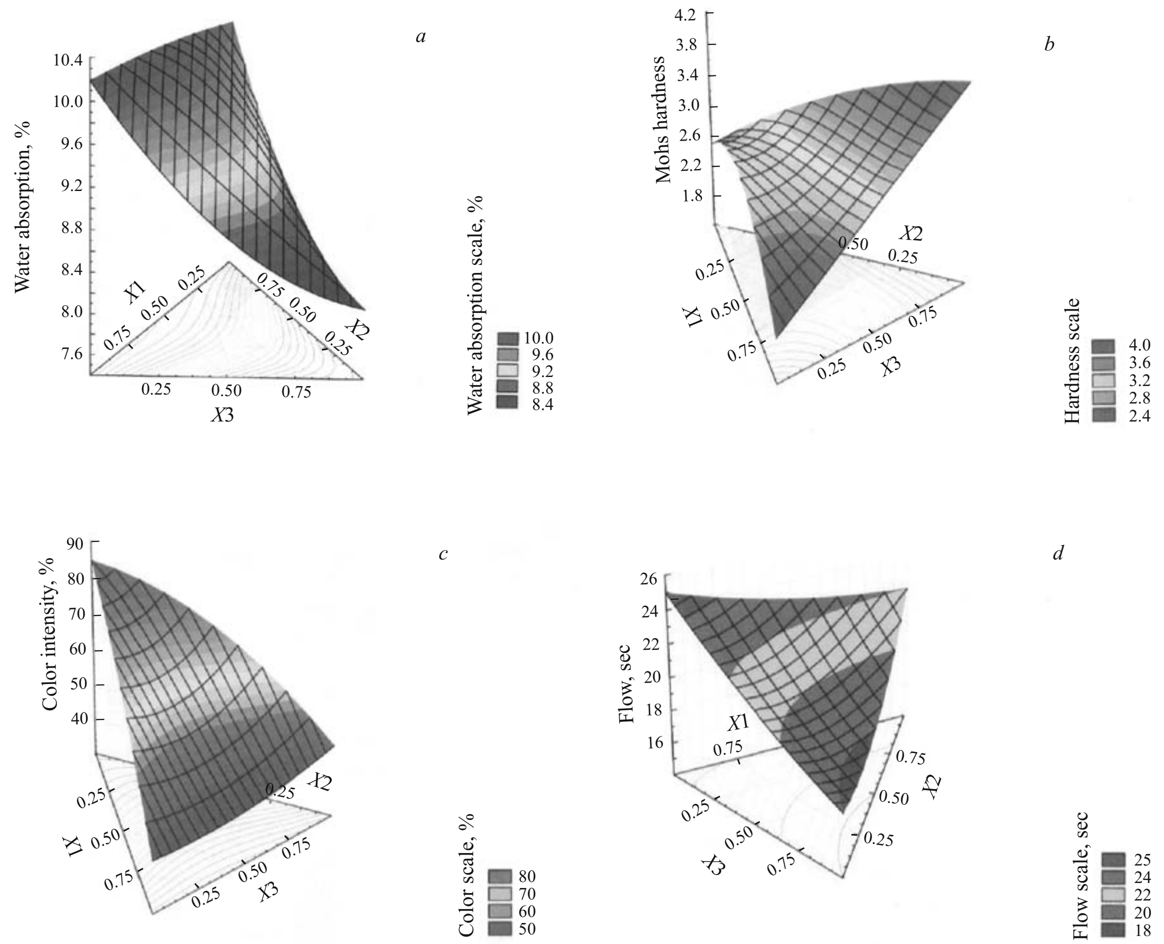

Fig. 1. Categorized response surfaces for water absorption (*a*), strength (*b*), color intensity (*c*) and fluidity (*d*) of the engobe and the projection of the surfaces onto a plane.

A palette of brick surface colors — white, dark-red, beige, green, blue, and others — was obtained on the basis of the bleached engobe. Intensely colored natural materials (ferruginous sand, clay) and artificial silicate pigments in amounts ranging from 3 to 7 wt.% were used as pigments.

The second problem of the present investigations was to optimize the rheological properties of the engobe slip by introducing electrolytes. Decreasing the moisture content of the slip and increasing its flow are problems of no less importance, since the slip was to be deposited on the green part after the part is formed. It is known that calcined soda, liquid glass, and sodium tripolyphosphate are used as electrolytes for multiple-clay mixes. In addition, introducing all these materials at the same time greatly intensifies the liquefaction process. The optimal amount of electrolytes was also determined using the simplex-centroid method of planning. The rate of efflux of equal volumes of slip from a container with a 6 mm in diameter opening was used as the response function characterizing the effectiveness of the electrolytes.

The experimental data and computed values of the flow of engobe slips are presented in Fig. 1. The greatest improvement of the flow of engobe slip was observed when sodium tripolyphosphate was introduced or when sodium tripolyphosphate was used together with liquid glass. The ratio of electrolytes that corresponded to flow 17.5 sec with moisture content of the engobe slip 40% was taken as the optimal ratio.

The present investigations have made it possible to work out the optimal composition of light-colored engobe using red-firing clays with predominately the same composition that is used for manufacturing ceramic brick. A diverse palette of engobes was obtained by adding different pigments.

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